

What is Claimed:

1. A method of fabricating gradient-index microlenses in optical polymeric fluids using an ink-jet printhead, comprising:

depositing a first series of droplets of a first optical polymeric fluid having an index of refraction, from an ink-jet printhead, onto a substrate;

coalescing said first series of droplets to form the base portion of a partially formed microlens;

depositing a second series of droplets of a second optical polymeric fluid compatible with said first optical polymeric fluid from an ink-jet printhead onto the partially formed microlens, the second optical polymeric fluid having an index of refraction higher than that of said first optical polymeric fluid;

coalescing said second series of droplets to create a fully formed microlens having a base portion of the first optical polymeric fluid under a cap portion of the second optical polymeric fluid;

holding the formed microlens under conditions which permit inter-diffusion of the cap portion and the base portion to create a generally uniform axially gradient index of refraction in the formed microlens; and

solidifying the formed microlens after a time period calculated to retain a desired degree and uniformity of gradient in the index of refraction of the formed microlens;

wherein the formed microlens has a reduced focal spot for optical uses as compared to a non-gradient index microlens of the same character.

2. The method of Claim 1 wherein the step of depositing a second series of droplets of a second optical polymeric fluid compatible with the first optical polymeric fluid comprises

the step of depositing a second optical polymeric fluid having an index of refraction about .01 or greater than the index of refraction of the first optical polymeric fluid.

3. The method of Claim 2 wherein the depositing and coalescing steps are performed relatively simultaneously wherein previous drops are coalescing while additional drops are being deposited.

4. The method of Claim 3 wherein the step of depositing a first series of droplets of a first optical polymeric fluid is performed with a printhead heated to an elevated temperature selected to reduce the viscosity of the first optical polymeric fluid to less than about 40 centipoise.

5. The method of Claim 4 wherein the step of depositing a second optical polymeric fluid is performed with a printhead depositing the second series of droplets of a second optical polymeric fluid which is heated to an elevated temperature sufficient to reduce the viscosity of the second optical polymeric fluid to less than about 40 centipoise.

6. The method of Claim 3 wherein the steps of depositing first and second optical polymeric fluids comprise the steps of depositing first and second optical polymeric fluids selected from the group consisting of pre-polymers and polymers.

7. The method of Claim 6 wherein the steps of depositing first and second optical polymeric fluids comprises the step of depositing at least one of the fluids in the group consisting of polyimides; fluorinated polyimides; polyetherimides; polybenzocyclobutenes; polycarbonates; polyacrylics; fluorinated polyacrylics; modified cellulose/acrylics; polyquinolates; polystyrenics; polyesters; and polymers/pre-polymers comprising monomers having reactive functionality selected from epoxy, cyanato or maleimido groups.

8. The method of Claim 3 where in the step of depositing first and second optical polymeric fluids comprises the step of depositing at least one first or at best one second optical polymeric fluid which is heat or UV curable and the solidifying step is accomplished by applying heat or UV radiation to the formed microlens after the holding step.

9. The method of Claim 1 wherein at least one of the first and second optical polymeric fluids is a UV curable pre-polymer and further including the step of exposing at least one of the first or second optical polymeric fluids to UV radiation during the depositing step to help control the aspect ratio/shape of the formed microlens.

10. The method of Claim 1 wherein the step of depositing a first series of droplets of a first optical polymeric fluid from an ink-jet printhead onto a substrate comprises the step of depositing said first optical polymeric fluid onto a substrate having a surface treated to be non-wetting with respect to the first optical polymeric fluid to help control the aspect ratio of the formed microlens.

11. A method of fabricating an array of gradient-index microlenses in optical polymeric fluids using an ink-jet printhead, comprising:

providing an ink-jet printhead adapted to deposit a series of droplets of a first optical polymeric fluid from a first orifice and a second series of droplets of a second optical polymeric fluid from a second orifice, wherein the first and second optical polymeric fluids are compatible and the second optical polymeric fluid has a higher index of refraction than the first optical polymeric fluid;

operating the first orifice to deposit a series of droplets of the first optical polymeric fluid at each of a plurality of sites on a substrate to form the base portion of a partially formed microlens at each of the plurality of sites on the substrate;

operating the second orifice to deposit a series of droplets of the second optical polymeric fluid at each of the plurality of sites on the substrate to form cap portions of the second optical polymeric fluid over the base portions of first optical polymeric fluids at the plurality of sites to form an array of microlenses having a base portion of the first optical polymeric fluid and a cap portion of the second optical polymeric fluid;

holding the array of microlenses at a temperature for a diffusion time which permits inter-diffusion of the cap portion and base portion of each microlens to create a generally uniform intermediate zone having a generally uniform axially gradient index of refraction in the microlens in said array; and

solidifying the microlenses in said array to maintain the axial gradient that has been formed in the array of microlenses.

12. The method of Claim 11 wherein the step of operating the second orifice to deposit a series of droplets of the second optical polymeric fluid at each of the plurality of sites comprises the step of depositing a second optical polymeric having an index of refraction about .01 or greater than the index of refraction of the first optical polymeric fluid.

13. The method of Claim 12 wherein the substrate is moved relative to the printhead in order to move the orifices from site to site.

14. The method of Claim 12 wherein the printhead is moved relative to the substrate in order to move the orifices from site to site.

15. The method of Claim 11 wherein the step of depositing a series of droplets of the first optical polymeric fluid includes the step of heating said first optical polymeric fluid to an elevated temperature sufficient to reduce the viscosity of the first optical polymeric fluid to less than about 40 centipoise.

16. The method of Claim 15 wherein the step of depositing a series of droplets of the second optical polymeric fluid includes the step of heating the second optical polymeric fluid to reduce the viscosity of the second optical polymeric fluid to less than about 40 centipoise.

17. The method of Claim 12 wherein the steps of operating the first and second orifices to deposit said first and second optical polymeric fluids comprise the step of depositing first and second optical polymeric fluids selected from the group consisting of pre-polymers and polymers.

18. The method of Claim 16 wherein the steps of operating the first and second orifices to deposit first and second optical polymeric fluids comprises the step of depositing said first and second optical fluids wherein at least one of the fluids come from the group consisting of polyimides; fluorinated polyimides; polyetherimides; polybenzocyclobutenes; polycarbonates; polyacrylics; fluorinated polyacrylics; modified cellulose/acrylics; polyquinolates; polystyrenics; polyesters; and polymers/pre-polymers comprising monomers having reactive functionality selected from epoxy, cyanato or maleimido groups.

19. The method of Claim 12 wherein the steps of depositing a series of droplets of the first and second optical polymeric fluids comprise the step of depositing first or second optical polymeric fluids which are heat or UV-curable and the solidifying step is accomplished by the step of applying heat or UV radiation to the formed microlens.

20. The method of Claim 11 wherein the step of operating the first orifice to deposit a series of droplets of the first optical polymeric fluid at each of a plurality of sites on a substrate comprises the step of depositing said first optical polymeric fluid onto a substrate having a surface treated to be non-wetting with respect to the first optical polymeric fluid to help control the aspect ratio of the base portion of the partially formed microlens.